Basics of Remodeling, Hypertrophy, and LV Mass

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ASE Board Review Course

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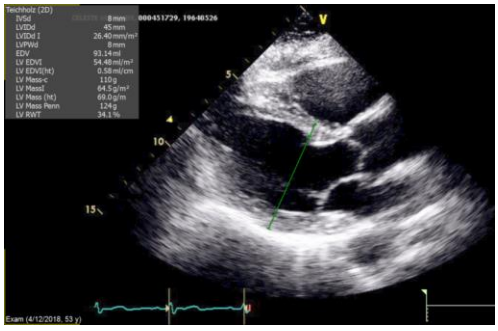
No Relevant Disclosures

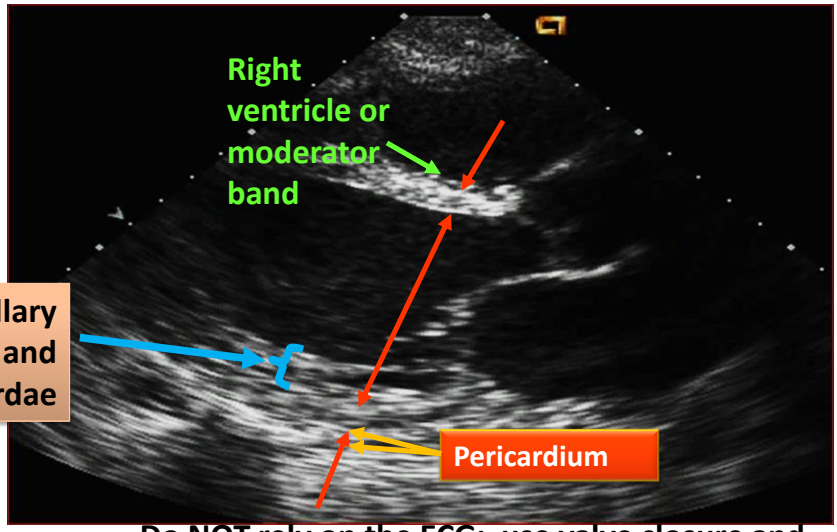
University of Massachusetts Medical School

What can be said about M mode calculations of LV mass?



1. The M mode cube formula takes into account shape distortions caused by valvular disease, such as AR, but not those caused by AS
2. There are as much data accumulated with 2D mass measurements as there are for M mode measurements
3. The method produces results which are similar to MRI
4. The formula used is called the cube formula because linear dimensions are cubed
5. Calculations are sensitive to changes caused by antihypertensive therapy, such as ACE-inhibitors, etc.

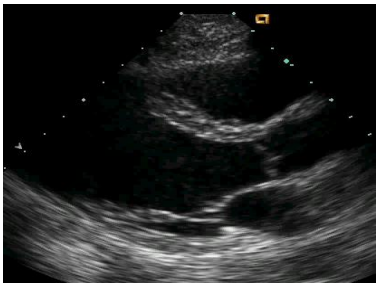
2D Measurements

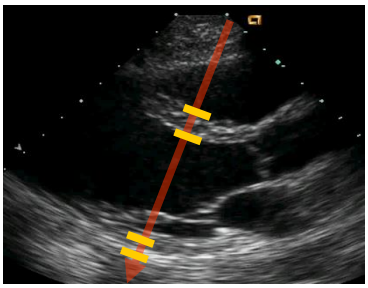


R.Hahn, Columbia

Do NOT rely on the ECG: use valve closure and largest diameter!!!

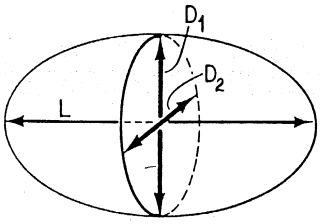
LV Dimensions Quantification

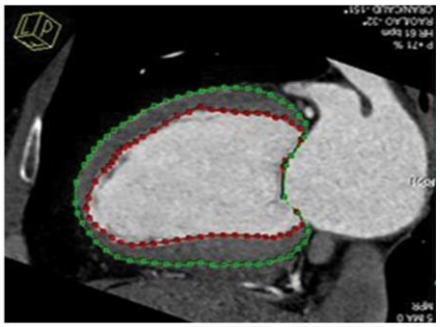




1. From **parasternal long-axis view**.
2. Values should be carefully obtained **perpendicular to the LV long axis**
3. Electronic Calipers at the interface between myocardial wall and cavity, and between wall and pericardium
4. Measured **at or immediately below the level of the mitral valve leaflet tips**
5. Linear measurements **obtained from 2D echocardiographic**

Single dimension, i.e., representative only in normally shaped ventricles



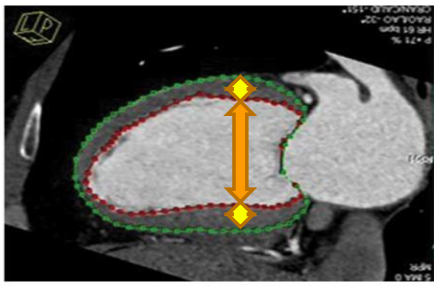


Assumes prolate ellipsoid shape

LV volume = $\prod/3$ (LVIDd)^3

assumes $D_1 = D_2 = L/2$

Concept: subtract inner shell volume from outer shell volume



Outer shell= (5 +1+1)^3

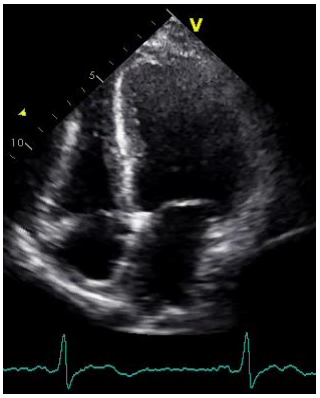
Inner shell= 5^3

Shell volume=343-125=118 ml

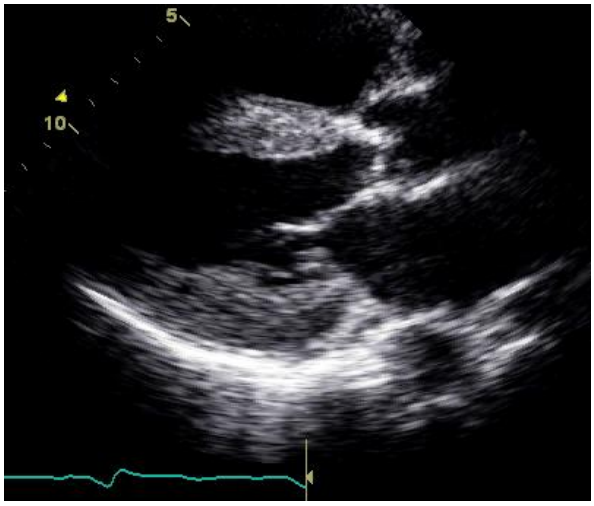
Shell volume*1.04 g/ml=122 g

43 year old health assistant
Severe resistant HTN

LT
BSA 2
Height 64”



LV data



- **LVIDd 4.2 cm**
- **IVSTd 1.4 cm**
- **PWTd 1.4 cm**
- **RWTd 0.64**
- **LV mass 239 g**
- **LVMi 119 g/M2**

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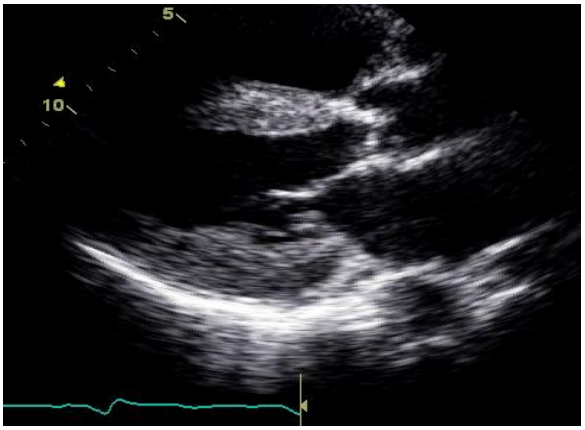
Which phrase best describes the LV in LT?



1. Normal
2. Concentric hypertrophy
3. Eccentric, dilated hypertrophy
4. Concentric remodeling
5. Eccentric hypertrophy

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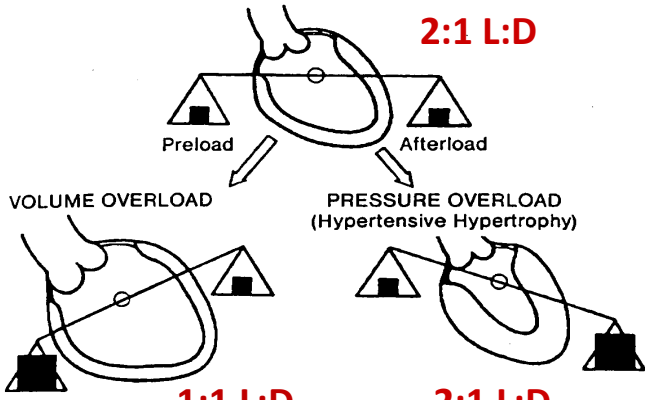
Pressure and Volume Load and Cardiac Remodeling

L to D ratio decreases with increasingly shperical LV

AR

MR

Increased CO



Hypertension

AS

Table 6 Normal ranges for LV mass indices

	Women	Men
Linear method		
LV mass (g)	67–162	88–224
LV mass/BSA (g/m²)	***43–95***	***49–115***
Relative wall thickness (cm)	0.22–0.42	0.24–0.42
Septal thickness (cm)	***0.6–0.9***	***0.6–1.0***
Posterior wall thickness (cm)	***0.6–0.9***	***0.6–1.0***
2D method		
LV mass (g)	66–150	96–200
LV mass/BSA (g/m²)	***44–88***	***50–102***

Bold italic values: recommended and best validated.

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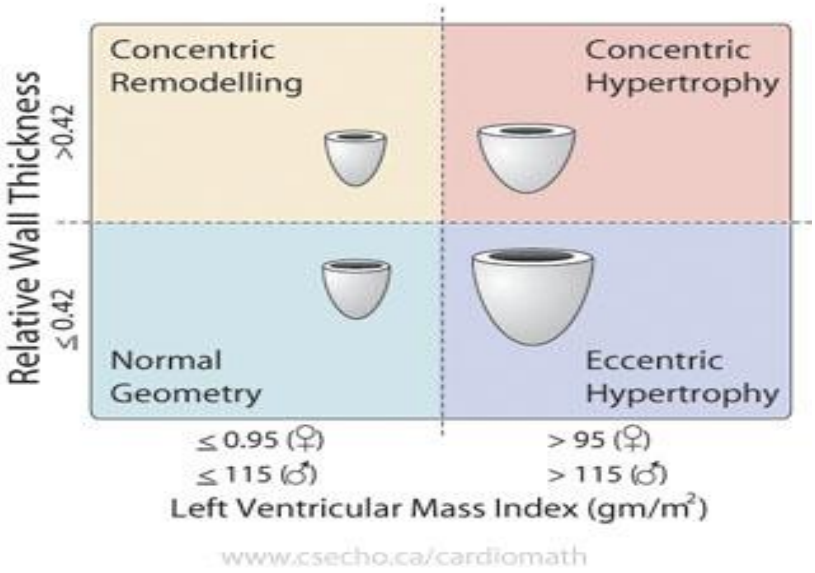

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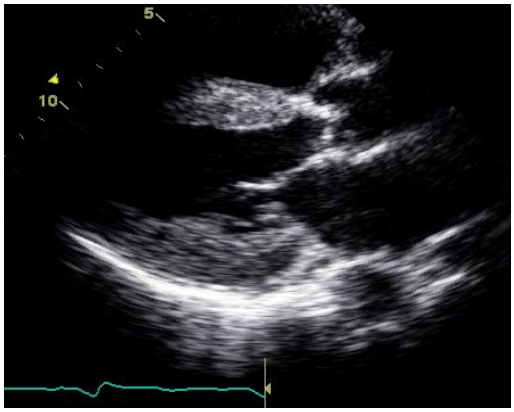
What can be said about the appropriate use of TTE in this patient



1. **TTE is appropriate for initial evaluation of patients with suspected hypertensive heart disease**
2. **Follow up TTE is appropriate in HHD even if there is no change in clinical status**
3. **Serial TTE has uncertain appropriateness for gauging change in LV mass in response to antihypertensive therapy**
4. **Follow up TTE is inappropriate for patients with hypertension even when there is a change in clinical status**

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Appropriate use of TTE in patients with hypertension

Table 6 TTE for evaluation of hypertension, HF, or cardiomyopathy

Indication		Appropriate Use score (1–9)
	Hypertension With TTE	
67.	• Initial evaluation of suspected hypertensive heart disease	A (8)
68.	• Routine evaluation of systemic hypertension without symptoms or signs of hypertensive heart disease	I (3)
69.	• Re-evaluation of known hypertensive heart disease without a change in clinical status or cardiac exam	U (4)
	HF With TTE	
70.	• Initial evaluation of known or suspected HF (systolic or diastolic) based on symptoms, signs, or abnormal test results	A (9)
71.	• Re-evaluation of known HF (systolic or diastolic) with a change in clinical status or cardiac exam without a clear precipitating change in medication or diet	A (8)
72.	• Re-evaluation of known HF (systolic or diastolic) with a change in clinical status or cardiac exam with a clear precipitating change in medication or diet	U (4)
73.	• Re-evaluation of known HF (systolic or diastolic) to guide therapy	A (9)
		(*Continued*)

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What can be said about M mode calculations of LV mass?

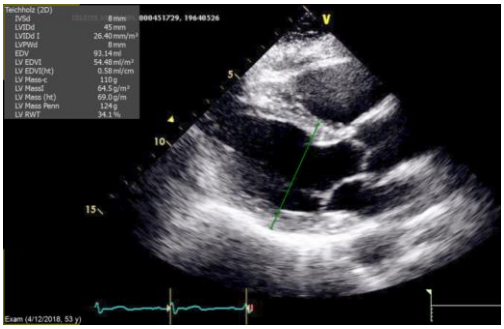

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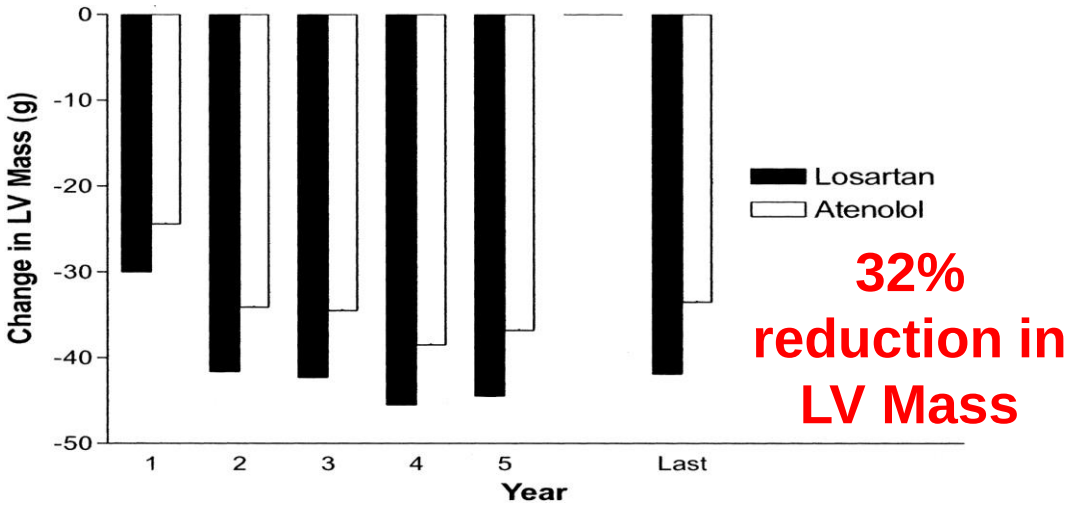
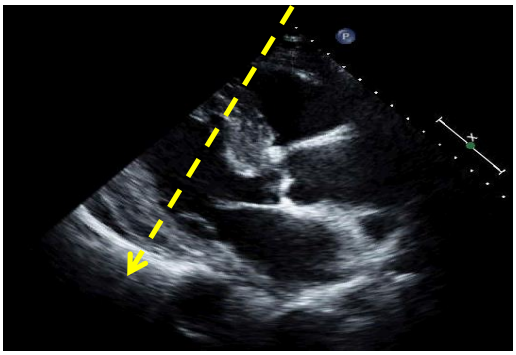
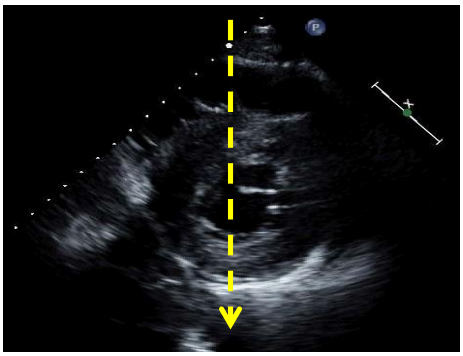
Figure 4. LV mass (y axis) was reduced more in patients randomized to losartan than atenolol.



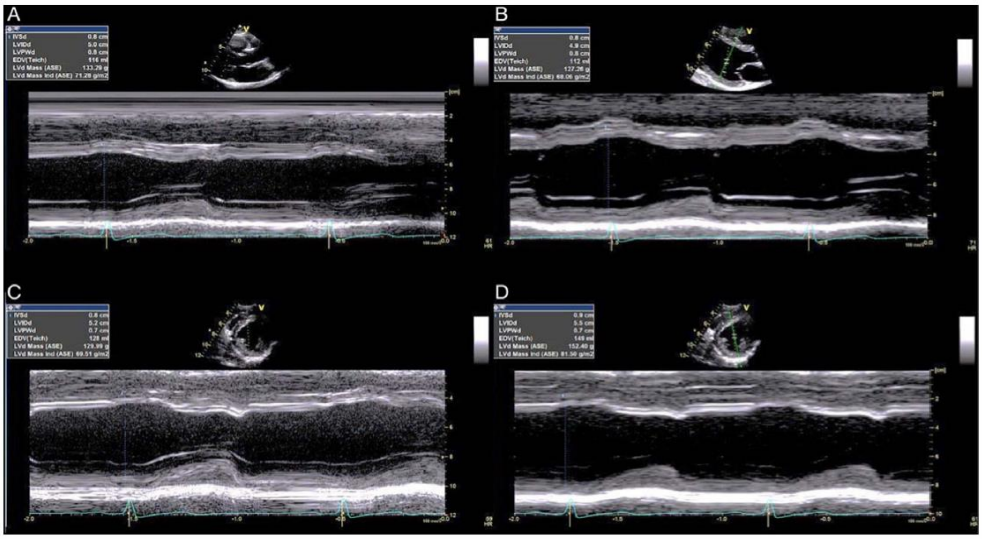
Richard B. Devereux et al. Circulation. 2004;110:1456-1462

American Heart Association.





Off axis preferred



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A patient undergoes echo and MRI on the same day for evaluation of mitral regurgitation. What will you find?

1. 3D volumes by echo will be smaller than MRI volumes; EF will be the same
2. Systolic and diastolic volumes will be smaller by MRI; EF will be similar
3. Systolic and diastolic volumes will be larger by MRI; EF will be similar
4. Echo and MRI should be similar, as long as careful attention to detail was paid and no hemodynamic change took place

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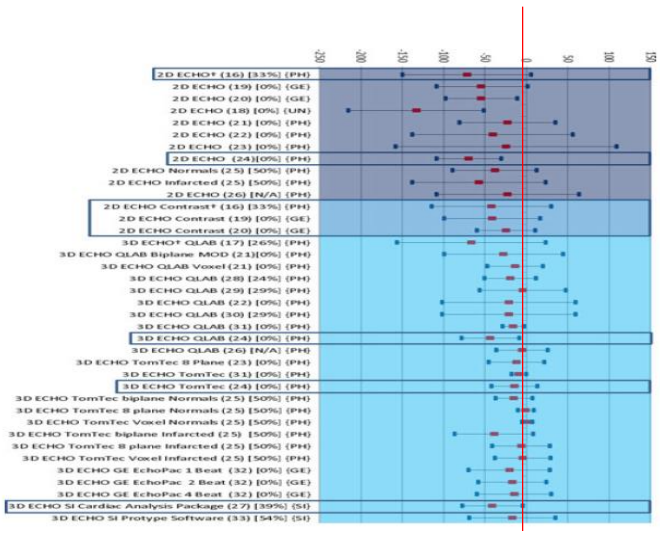
Echo v MRI

LV EDV



Wood Echocardiography 2013

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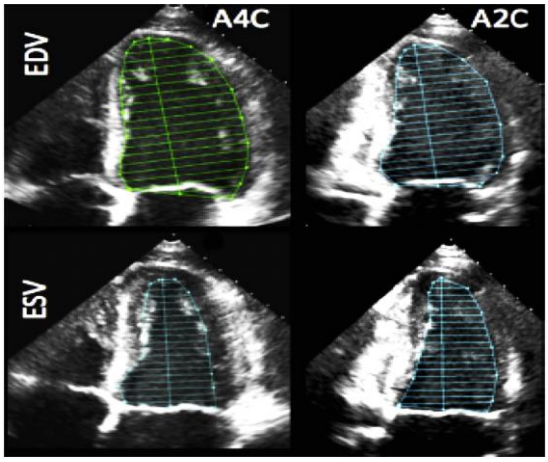
Left Ventricular Volumetric Measurement



Biplane Disk Summation

- Corrects for shape distortions
- Less geometrical assumptions compared with linear dimensions

But……

- Apex frequently foreshortened
- Endocardial dropout
- Blind to shape distortions not visualized in the apical two- and four-chamber planes

What explains discrepant volumes by echo and MRI in normal individuals?

1. **Changing hemodynamic conditions**
2. **Border tracing errors**
3. **Geometric assumptions**
4. **Image plane (e.g. foreshortening)**

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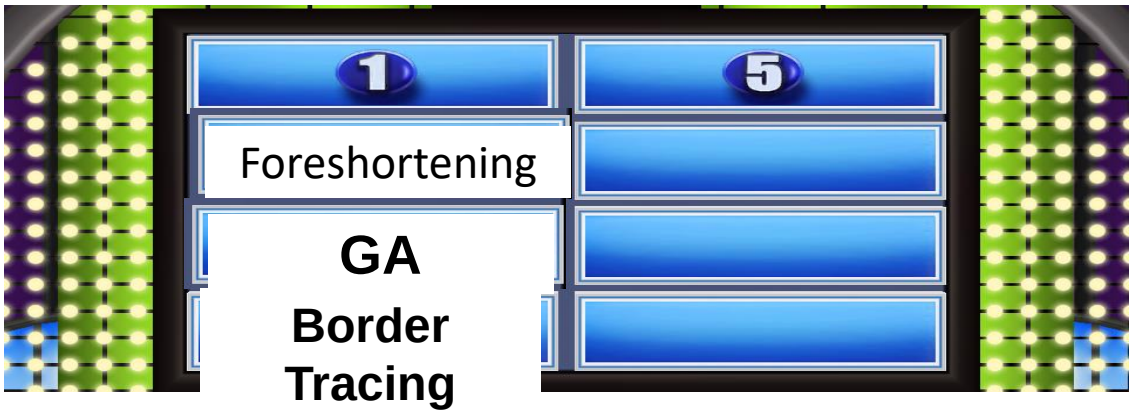
Underestimation of LV Volumes by BP Simpson's



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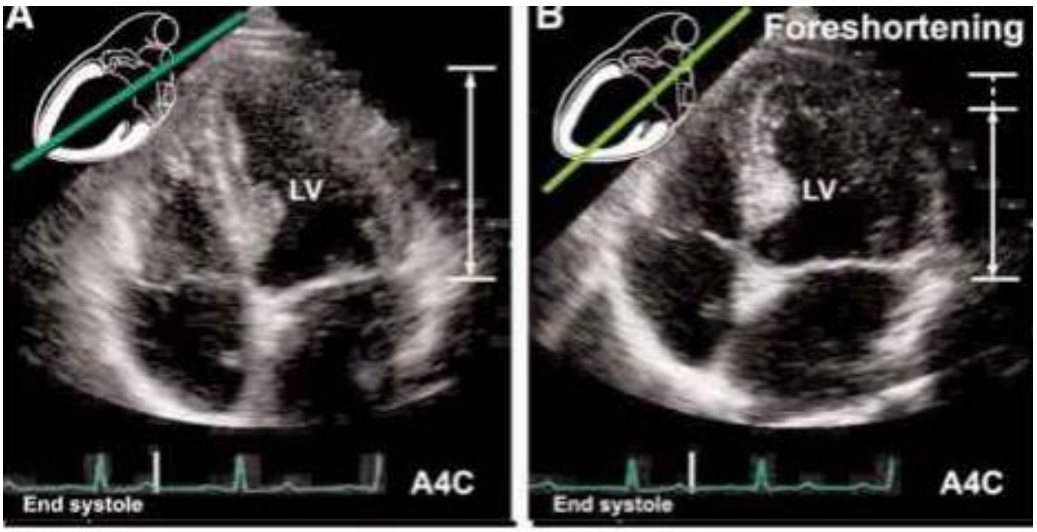
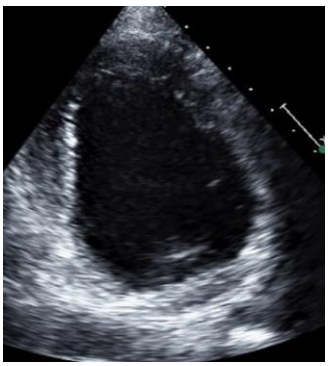
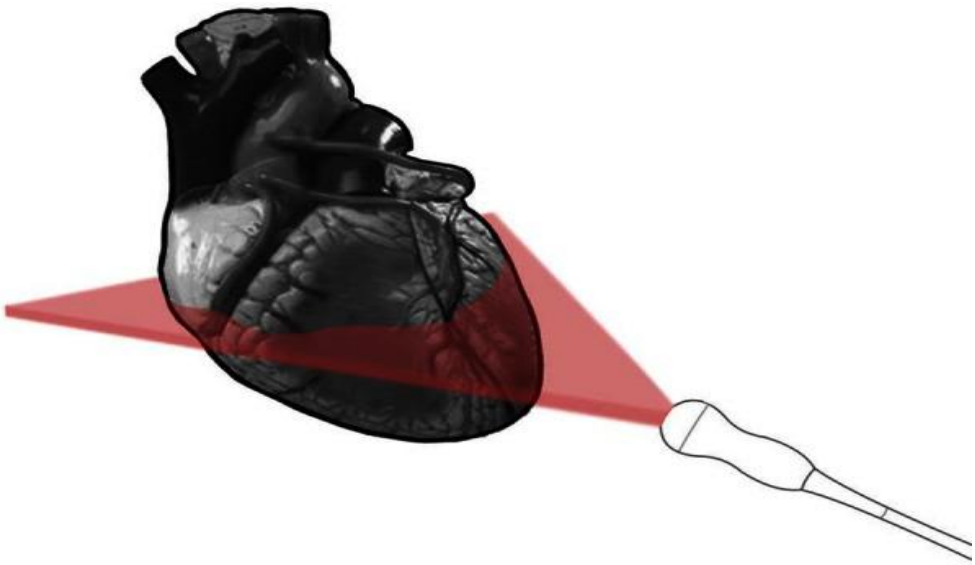


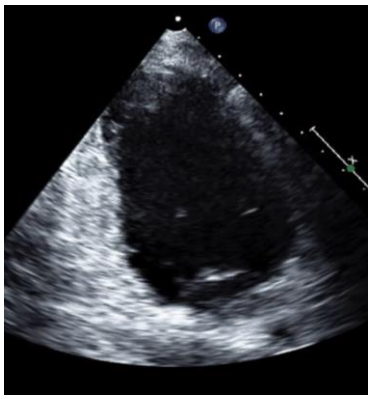


LVV A4c 115 cc
LVV A2c 135 cc
EF 58%
LVL 7.2 cm

25

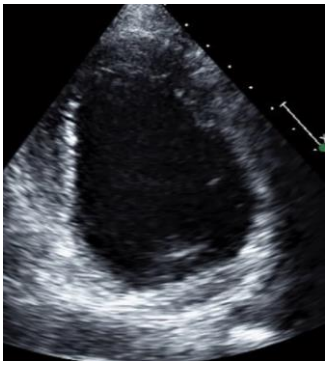


One ribspace downward later….



LVV A4c
138 cc
LVV A2c
142 cc
LV L 8 cm
EF 58%

27



Clues:

globular LV

discrepancy in LV lengths

apex is thickening

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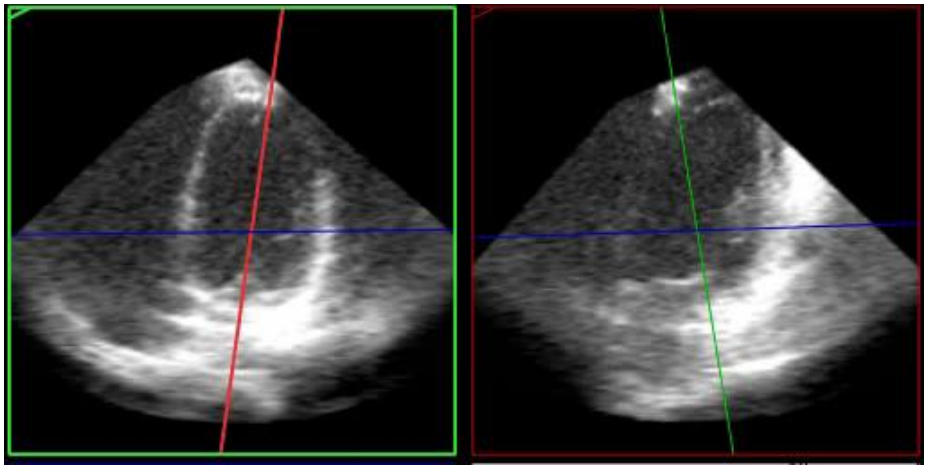

Video from Dr. Lang, 2003

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CLINICAL INVESTIGATIONS
REAL-TIME 3D ECHO

Relative Importance of Errors in Left Ventricular Quantitation by Two-Dimensional Echocardiography: Insights From Three-Dimensional Echocardiography and Cardiac Magnetic Resonance Imaging

Ebere O. Chukwu, MD, Eddy Barasch, MD, Dennis G. Mihalatos, MD, Alan Katz, MD, Justine Lachmann, MD, Jing Han, PhD, Nathaniel Reichek, MD, and Aasha S. Gopal, MD, *Roslyn and Stony Brook, NY*

three-dimensional work showed that approximately 50% of 2-dimensional echocardiographic views by experienced sonographers are not optimally positioned with respect to displacement and angulation.[1] Specifically, only 12% of apical 4-chamber and 2-chamber views were orthogonal.[1]

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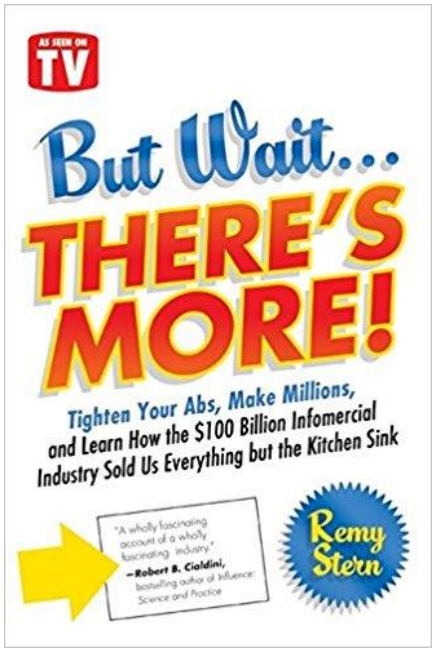
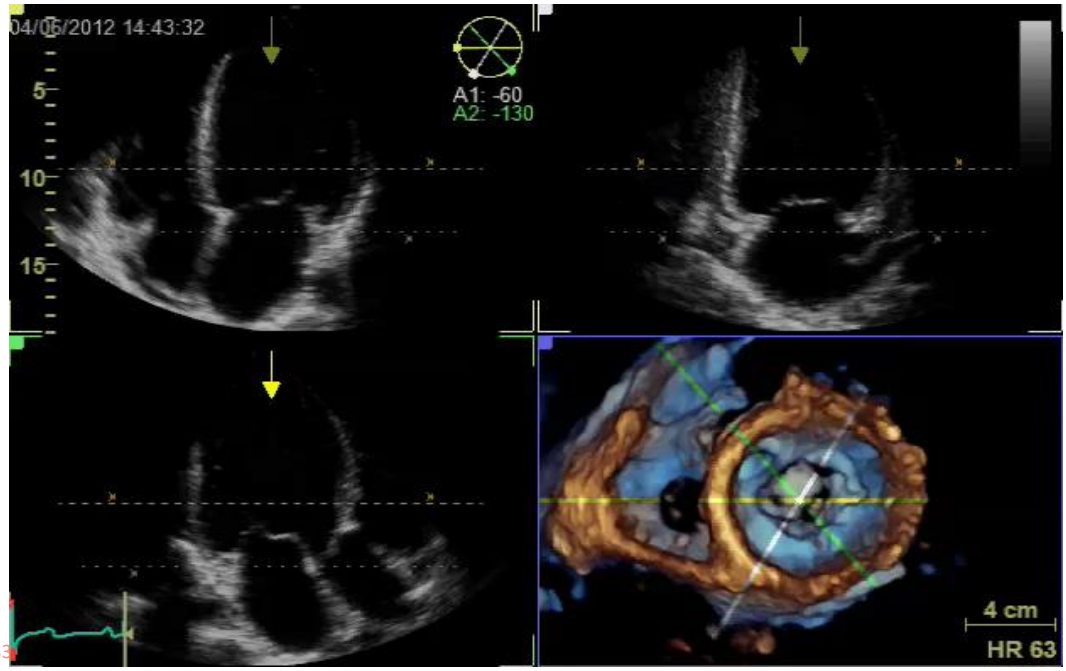
	2D	3D	CMR
EDV	92	131	130
ESV	30	52	54
EF	68	60	58

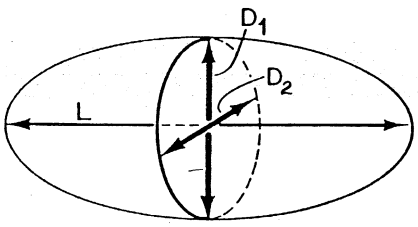
Error sourc	Normal controls
EDV	
IP	58.3
GA	33.3
BT	8.3
Total	99.9
ESV	
IP	52
GA	29
BT	19
Total	100
EF	
IP	48
GA	19
BT	33
Total	100

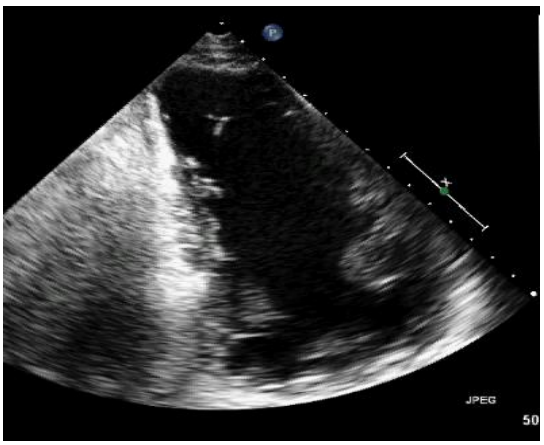
31



32


04/05/2012 14:43:32
A1: -60
A2: -130
5
10
15
4 cm
HR 63


D1
D2
L


JPEG

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	2D	3D	CMR
EDV	155	208	212
ESV	96	137	126
EF	42	37	37

Error source	Patients with MIs
EDV	
IP	33.3
GA	42.4
BT	24.2
Total	99.9
ESV	
IP	29
GA	44
BT	27
Total	100
EF	
IP	19
GA	15
BT	67
Total	101

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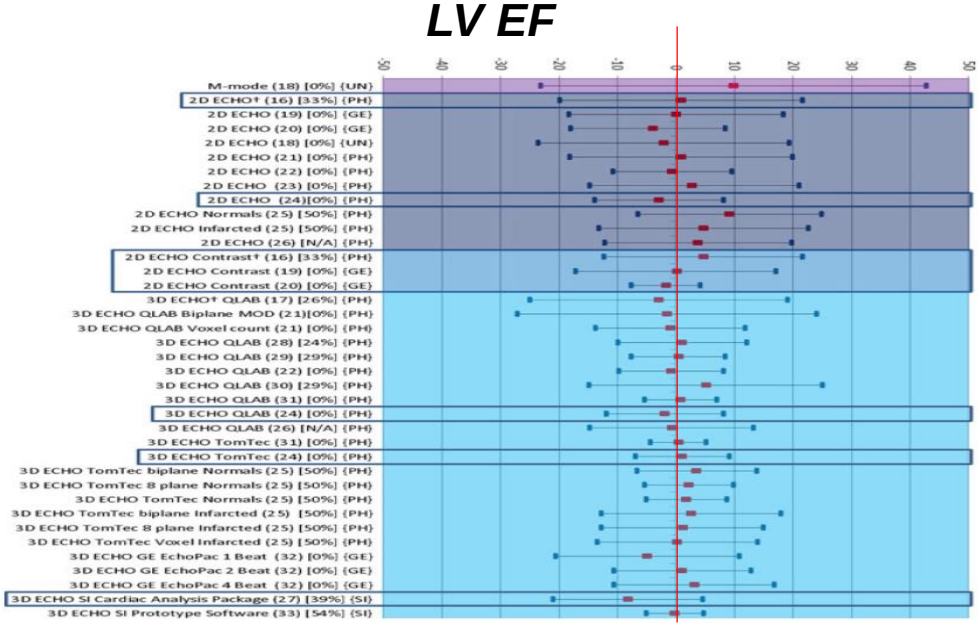
Left Ventricular Ejection Fraction

	Normal	Mild	Moderate	Severe
2015	>52	51-41	40-30	<30
2005	>55	54-45	44-30	<30

Echo v MRI

LV EF



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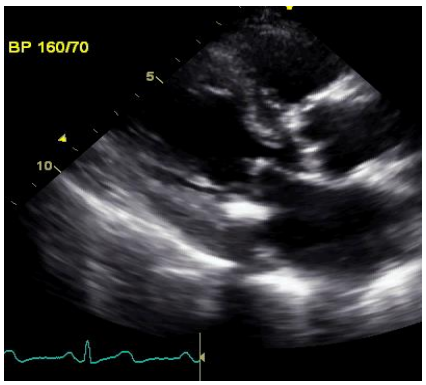
How does the LV remodel with aging?



94 year old Hypertension

1. **BSA indexed systolic and diastolic volumes both increase with age**
2. **BSA indexed systolic and diastolic volumes both decrease with age**
3. **BSA indexed systolic volume increases and and diastolic volumes decrease with age**
4. **BSA indexed systolic volume decreases and end diastolic volumes increase with age**

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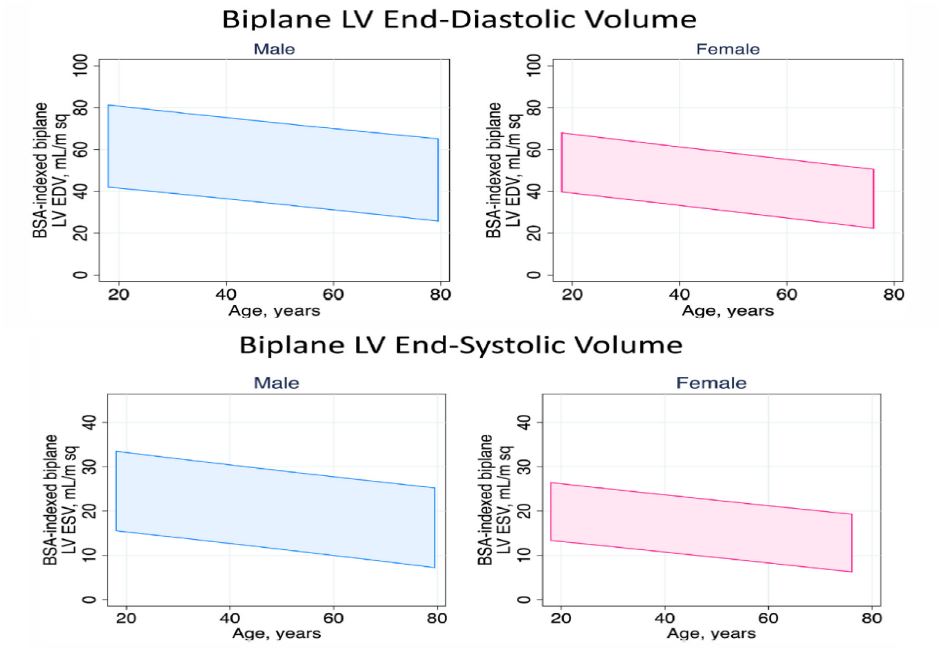

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Left Ventricular Ejection Fraction

	Normal	Mild	Moderate	Severe
2015	>52	51-41	40-30	<30
2005	>55	54-45	44-30	<30

Left Ventricular Ejection Fraction

Male

	Normal	Mildly	Moderately	Severely
LVEF	52-72	41-51	30-40	<30

Female

	Normal	Mildly	Moderately	Severely
LVEF	54-74	41-53	30-40	<30

Mea culpa

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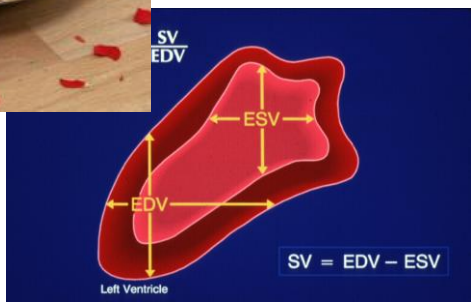
Sacred Icons

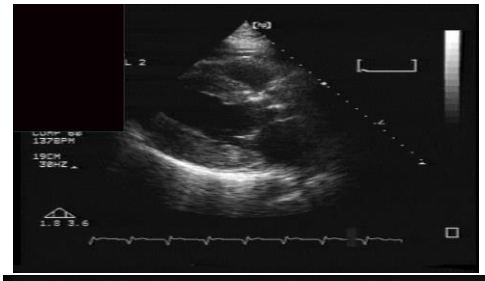


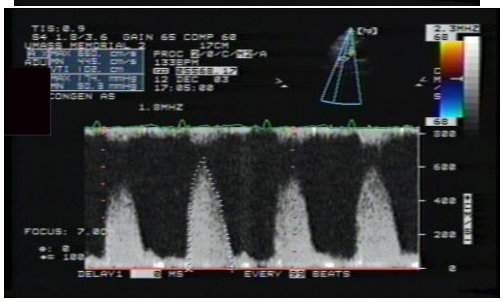
"I come to praise the EF, not to bury it"

Pitfalls of the EF

- Load
- Pump function
- Regional function

Aortic Stenosis



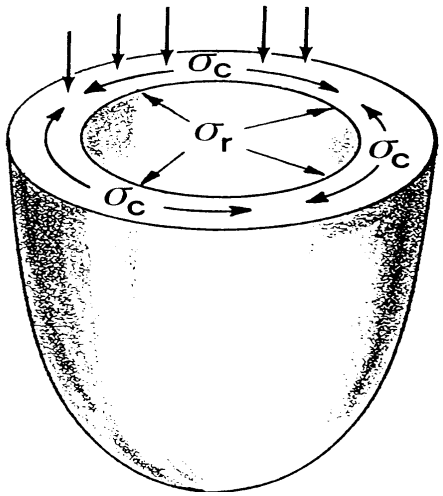


Prototype afterload excess lesion

"no bad myocytes…only bad loading conditions"

Contractility preserved even with markedly reduced EF

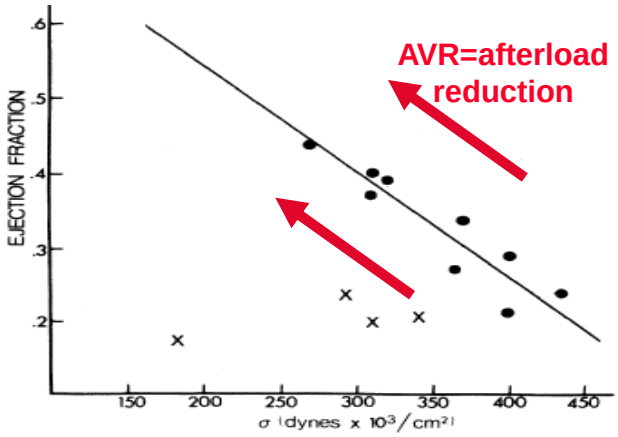
Afterload = Wall stress



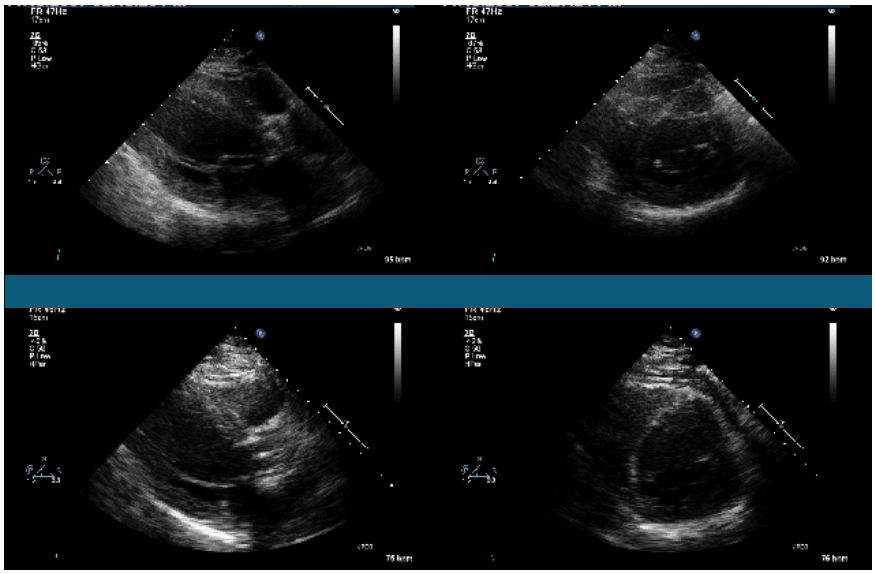
Afterload proportional to heart size and pressure and inversely to wall thickness

$$\sigma = p \times r \; / \; th$$

Afterload reduction and EF

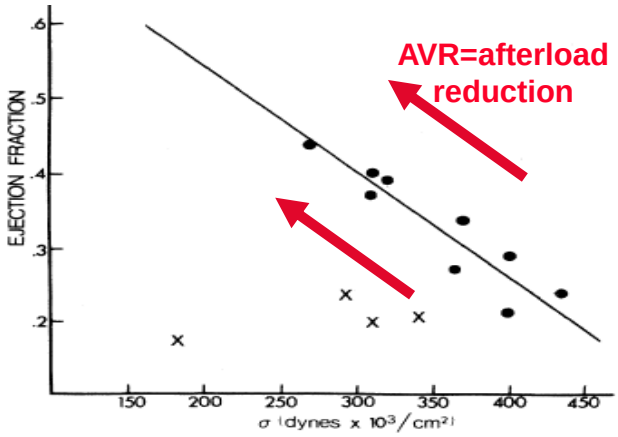


Carabello et al Circulation 1980

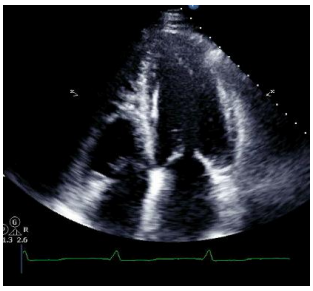


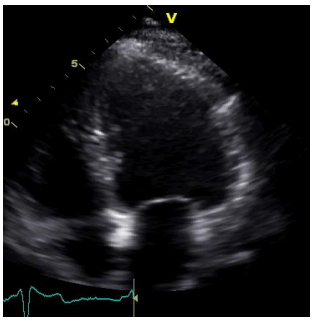
49

Afterload reduction and EF



Carabello et al Circulation 1980





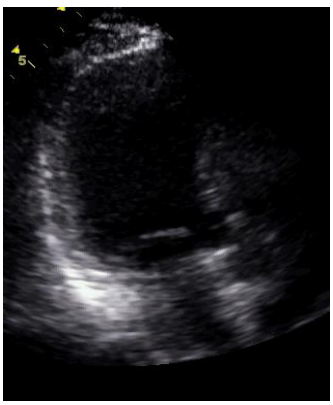
58 year old man

Class III HF
Untreated HTN

Treated HTN
Asymptomatic

51

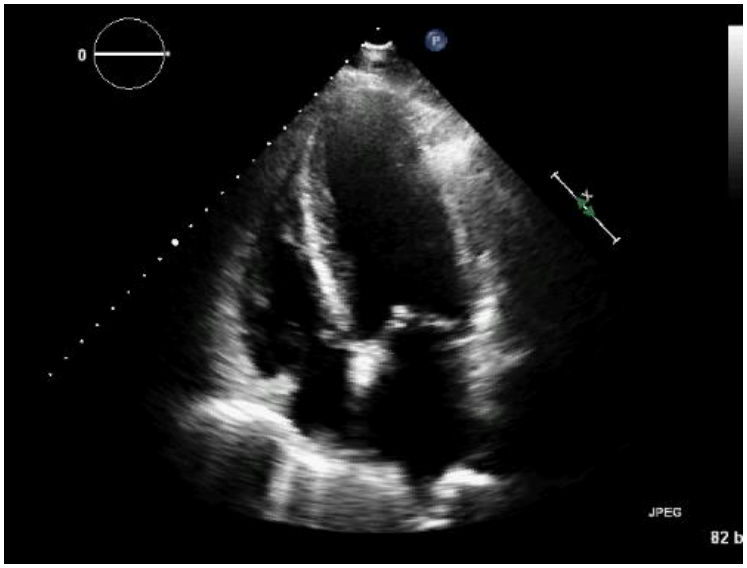
42 year old man
HTN, CKD
Now incarcerated
Taking Rx



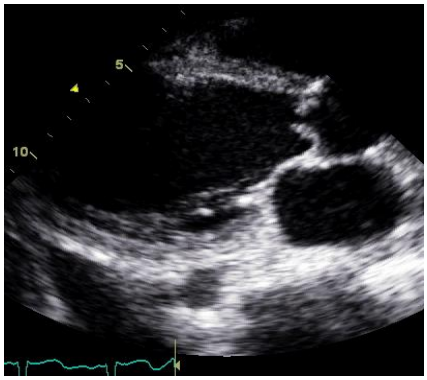
?

50 year old man

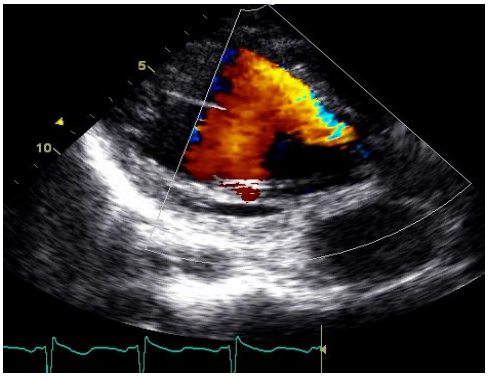
Poorly treated HTN



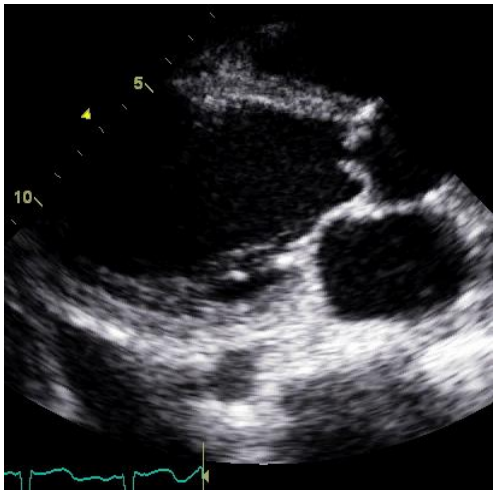
53



47 year old man
S aureus BE
LVIDd 7 cm
LV EF 48%



54



What best describes this situation?

1. LV dysfunction is due to reduced preload
2. LV dysfunction is due to reduced contractility
3. LV dysfunction is due to decreased afterload
4. LV dysfunction is due to increased afterload

55

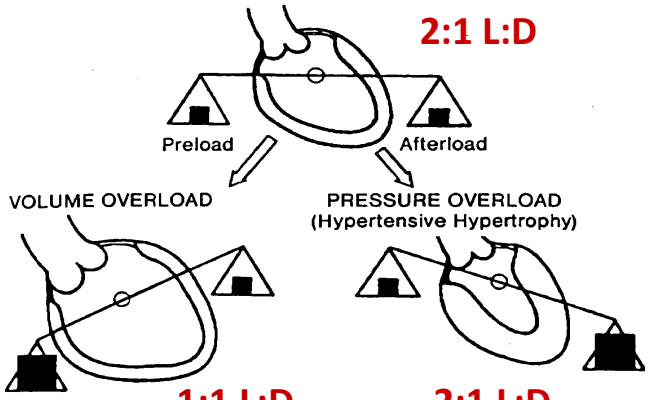
Pressure and Volume Load and Cardiac Remodeling

L to D ratio decreases with increasingly shperical LV

AR

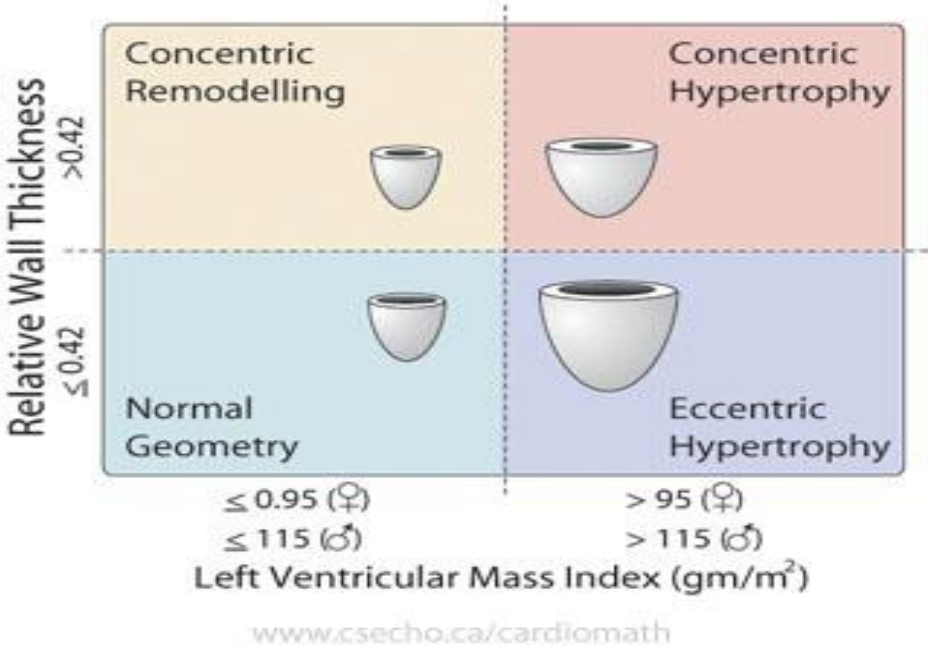
MR

Increased CO



Hypertension

AS



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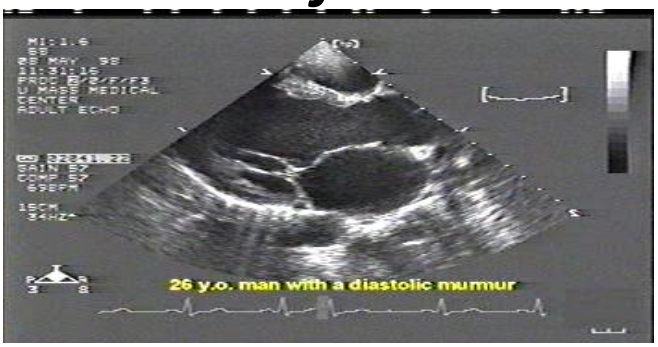
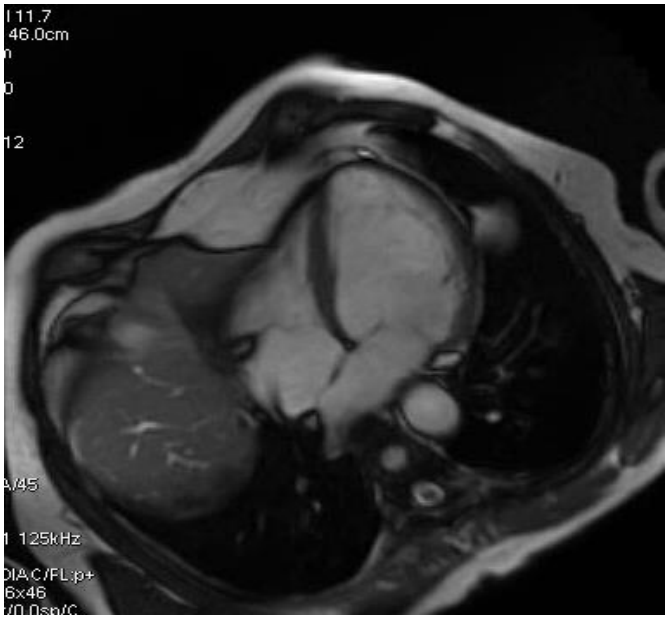
This just in: *chronic aortic and mitral regurgitation are afterload excess lesions*



- **Afterload excess (Laplace) p,r high**

$$\sigma = P \times r / th$$



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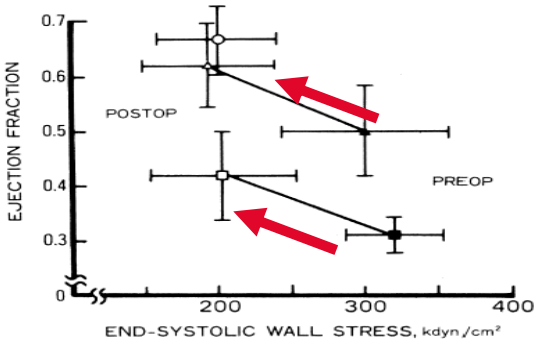
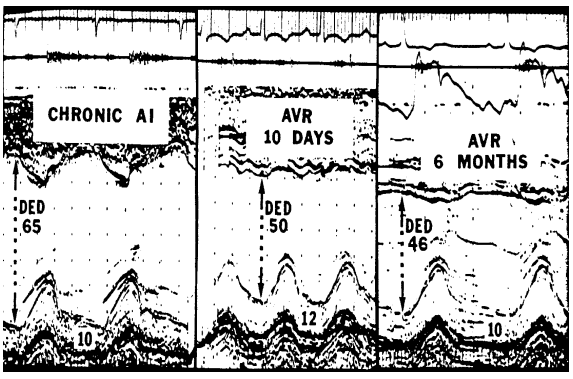
AVR associated with afterload reduction and “reverse” remodeling



Taniguchi Circ 1990



Carroll Circ 1985

Pitfalls of the EF

- Load
- Pump function
- Regional function

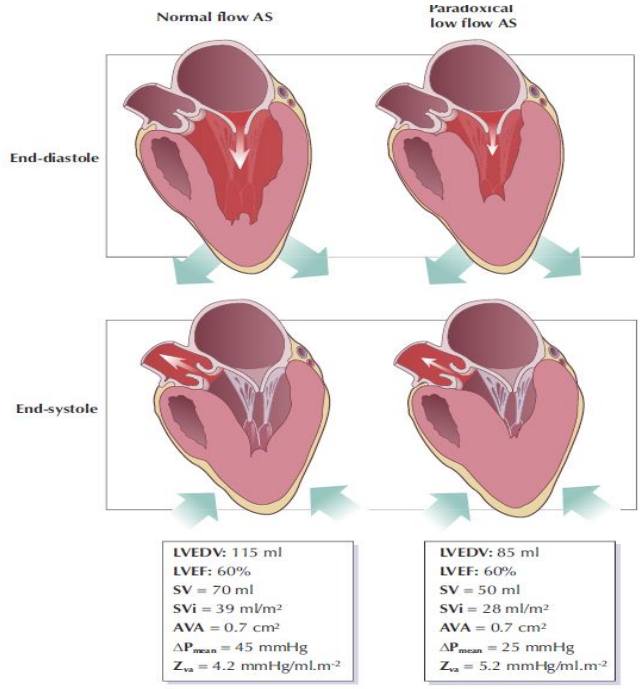
In Normal Sized Adult Patients with Heart Disase, Stroke Volume is closely correlated with Ejection Fraction

1. True
2. False

EF does not equal SV

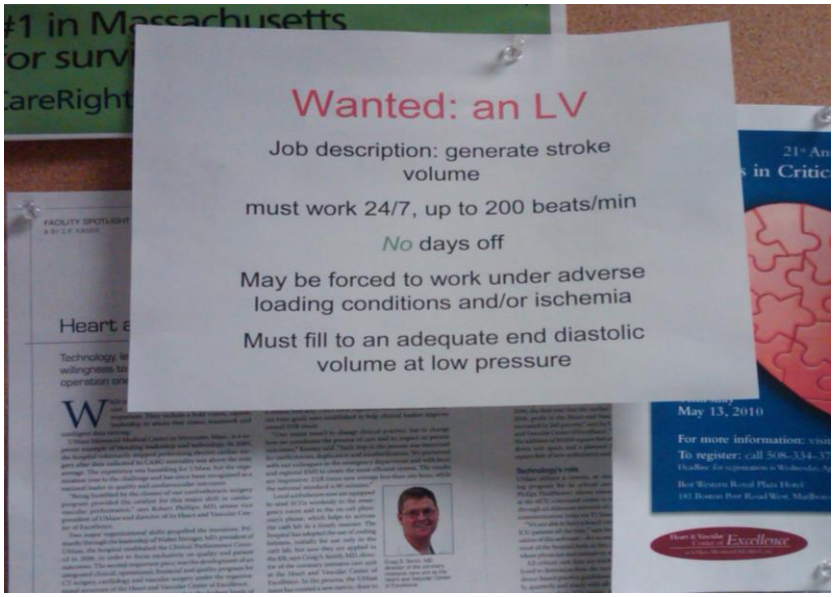
	LVIDd	EF	SV
normal	5	65	81
LVH	4.4	75	63
DCM	7.5	20	84

85% x  = small SV



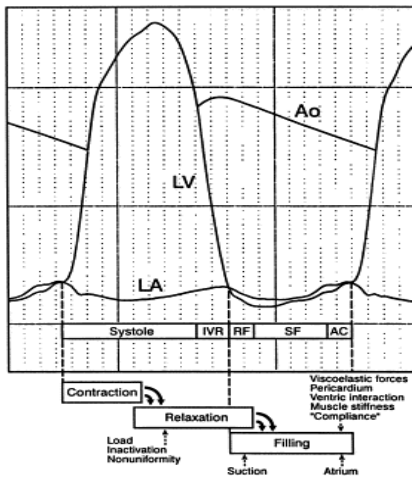
Paradoxical Low Flow AS

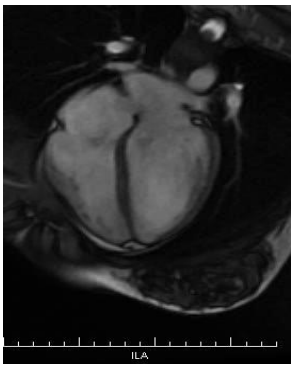
Pibarot and Dumesnil, *JACC Imaging 2009*



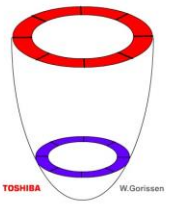
Pitfalls of the EF

- Load
- Pump function
- Regional function



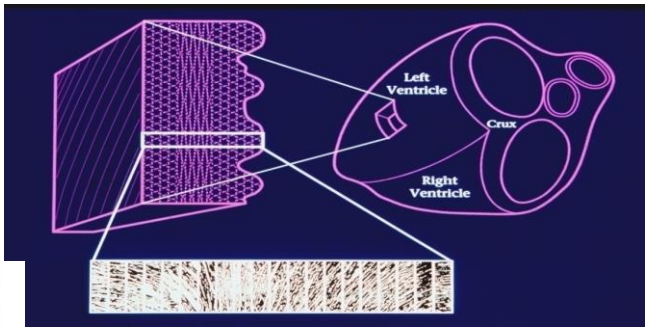


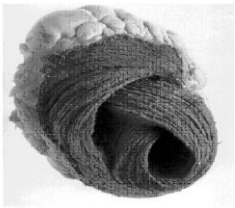
LV TWIST

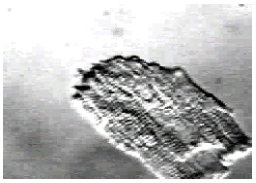


LV Systolic Function

Anatomic Considerations

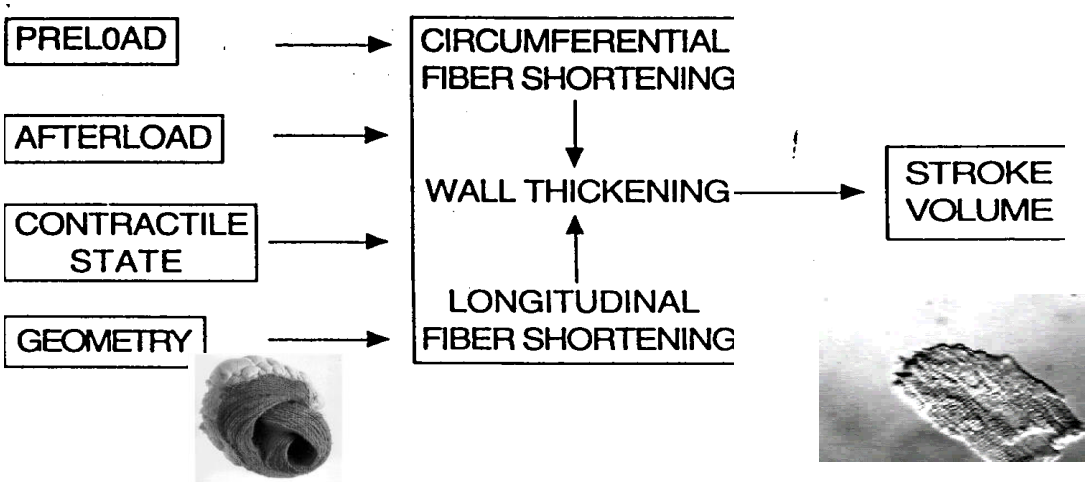


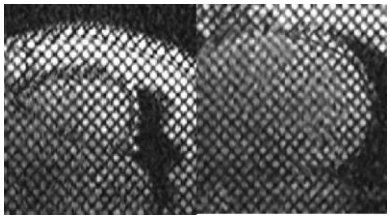




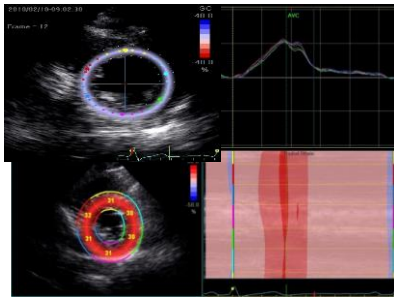
The Left Ventricle Job Description

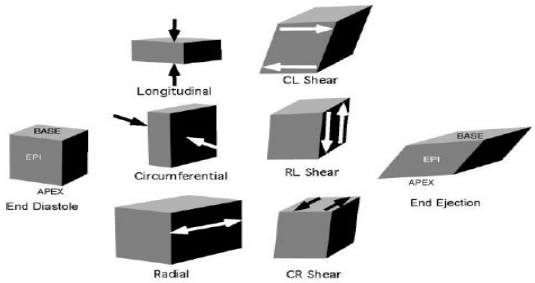
generate stroke volume





Courtesy: Dr. Vic Ferrari





Bogaert: AJP 2001